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5 October 1973

NIC # 19457
Packet Radio Note No. 74

INTERFERENCE LEVELS PRODUCED BY SPREAD SPECTRUM PACKET RADIO SYSTEMS

1.0 INTRODUCTION

This note addresses the subject of compatibility of spread and non-spread systems which may share the same frequency spectrum. Particular emphasis is given to the "near-far" problem which is a problem for systems such as mobile radio and packet radio where both transmitters and receivers may be spatially located in a random pattern.

2.0 BACKGROUND

There exists considerable interest today in the design of systems which can be assigned a frequency channel on a non-exclusive basis and systems that may compatibly share existing frequency allocations. In some environments, spread spectrum techniques have been effectively applied as a means of spectrum sharing and as a technique to provide protection from intentional jamming. However, in applying the experience obtained in some military environments to packet radio systems, it is important to recognize some major differences in the modes of operation, particularly with regard to the location of desired vs. undesired sources of radiation. For example, in the design of military satellite communications systems, the distance to synchronous orbit becomes a great equalizer of levels. Also, the spot beam approach being applied to

RECEIVED AT NIC OCTOBER 16, 1973.

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systems of recent design have provided additional protection of the desired signal from intentional jammers operating from protected sanctuaries. In the battlefield environment, a similar situation often exists in the area of short range communications where the intentional jamming source must operate from protected locations outside the normal area of communications of the battlefield systems.

This note addresses a somewhat different environment in which two quite different types of systems may wish to share the same frequency spectrum with a minimum of constraint on the spatial distribution of the components of the two systems. It is quite obvious, even without analysis, that the requirement of minimum constraint on spatial distribution implies high processing gain at the receiving end to minimize the effects of interference on the received spread signal and low spectral density in the radiated spread signal if interference to non-spread services is to be avoided. These requirements then imply very wide spread. However, under the conditions existing in the frequency bands suitable for packet radio, increasing the spread increases the number of interferers with which the system must contend. It is, therefore, not obvious that wide spread systems offer a solution to the compatible operation of digital packet radio systems in bands now allocated for quite different types of services. In any event, the character of the existing systems will at least have a strong influence on the design of the packet radio system. Only one aspect of this problem - that of interference to the existing or conventional type service - is addressed in this note.

The desire to operate the packet radio system in a portable mode with non-directive antennas implies that the lowest frequency consistent with reasonable antenna size and efficiency should be employed. However, the relatively high bit rate and the crowded condition of the spectrum at lower frequencies implies the use of a moderately high frequency in the VHF or UHF frequency range. Therefore, the frequencies in the range of 400 to 1500 MHz offer reasonable choices for packet radio. This range is occupied by numerous types of services, but mobile radio is a convenient service to be considered for frequency

sharing since this is a service which employs spatially distributed transmitters and receivers very similar to packet radio and employs transmitters of moderate power output, (i.e., they are not grossly over-designed from a transmission point of view like FM and TV broadcasting systems.) Also, the digital packet technique at low data rate is now being applied to dispatching type services operating in the mobile radio bands and increased use of this type service can be expected in view of the efficiency of the packet technique compared to voice in a dispatching type system. Another type of service that consumes a large part of the frequency spectrum of interest is UHF TV (470 to 890 MHz). Since this very valuable frequency resource is being very poorly utilized at the present time, sharing of the UHF TV band would be very attractive if it could be accomplished without interference to the broadcast service. Here, however, we have a somewhat different situation than in the mobile radio system in that we have relatively few interferers, but they are in the form of quite powerful broadcast transmitters (often powers in excess of 100 KW ERP). Also in this environment, we can be assured that almost any location we choose for operation will have a TV receiver that can be effected by radiation from the packet radio system.

From the rather broad summary above, it is clear that the use of spread spectrum techniques to provide compatible operation with other types of systems in a common band requires careful consideration and the requirements may be strongly influenced by the characteristics of the existing service that must be protected. This note addresses only the subject of protection of a conventional service such as mobile radio or broadcast TV. In order to make such an investigation, it is necessary to establish some criteria for allowed degradation. This was done in a somewhat arbitrary but reasonable manner as defined below.

3.0 APPROACH TO EVALUATION

In considering the interference to narrowband services, it is reasonable to assume that the interference produced by the spread system has the character of noise and has a flat spectral distribution over the acceptance band of the narrowband receiver. If this assumption is valid, then it can lead to a simplified approach to defining interference in terms of the loss of system sensitivity; that is, the effect of interference is equivalent to an increase in noise figure or a loss in transmitter power. Therefore the effect may be interpreted in terms of loss of area coverage of the existing system and this may be considered independent of the other system parameters of the narrowband system such as type of modulation, emphasis, transmitter output, etc. Arriving at a reasonable value of allowed degradation is a little more difficult. If the VHF or UHF band is to be shared with services which have now exclusive allocations, then the present occupants with exclusive licenses may object to any interference which causes a measurable degradation of service. However, many services such as mobile radio now share allocations and simply retransmit messages blocked by transmission by others. Since the packet radio system transmits in a random manner, it would appear that moderate levels of interference may be acceptable. Certainly higher levels of interference should be tolerable for intermittent services such as mobile radio than for full period services such as FM or television broadcasting. With the above thoughts in mind, a performance degradation to the narrowband service of 5 db was chosen for the examples below. This might appear a little excessive since this would result in a substantial loss in area coverage, but for any particular receiver in the existing service, this loss also has a time distribution because of the intermittent nature and spatial distribution of the packet system. The approach taken, then, is to compute the separation required between the narrowband receiver and the spread transmitter

for spread factors 0, 100 and 1000 for free space propagation and obstructed paths. The configuration is illustrated in Figure 1 below. The receiver employed by the narrowband service was assumed to have a noise figure of 8 db. Typical receivers within the frequency range of interest have noise figures in the range of 3 to 12 db.

4.0 INTERFERENCE CALCULATIONS

In the examples below we will concern ourselves only with the energy that falls within the limits of the first nulls of the spectrum since the spectral density is highest within these limits. However, in many practical situations energy beyond the first nulls may create an interference problem if not heavily filtered and if heavily filtered may limit the performance of the correlator used to separate the desired from the undesired signals.

Since omni antennas have been specified, the transfer of energy between antennas is simply the space loss equation, S.L. = 36.6 + 20 log f + 20 log d where f is in MHz and d is in miles. As indicated above, an interference level 5 db above the receiver noise power with an 8 db noise figure is assumed. If one considers only free space propagation and assumes an interferer at this level present at any location, then this would result in a reduction in the radius of coverage to 0.55 of that with no interference. This is equivalent to an area of coverage of only about 30% of that without interference. If one assumes that the propagation loss varies on the 4th power of the distance, then 5 db allowed degradation would result in less percentage reduction of area. However, above figures make no allowance for the statistics of transmission from any one location or the statistics of the distribution of the packet radio terminals among the receivers with which they may interfere.

4.1 Parameters Assumed for Examples

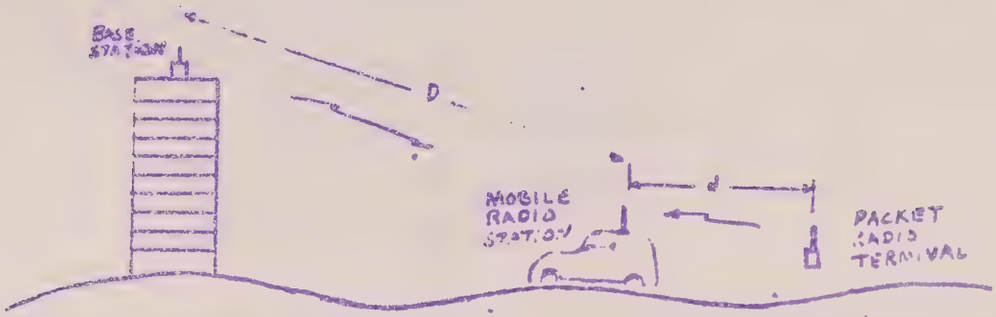
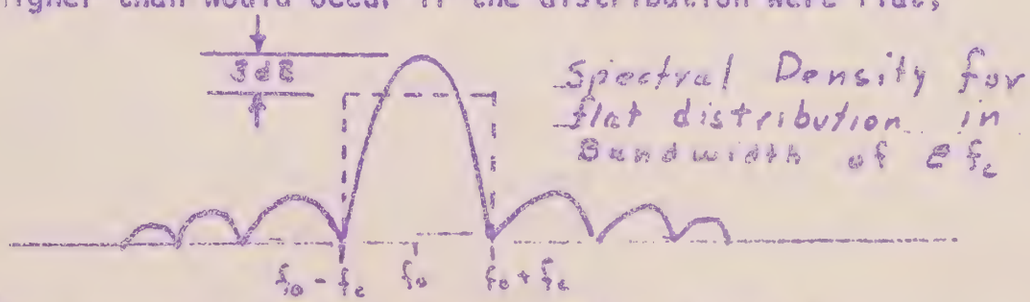


Figure 1

ASSUMED CONDITIONS

PARAMETER	MOBILE RADIO TERM	PACKET RADIO TERM
Noise Figure	8 db	-
R & T Antenna	Omni	Omni
TX Power	(Don't care)	10 watts (+40 dbm)
Spread Factor	-	100 and 1000
Data Rate	-	100 KB/S
Type of Modulation	(Don't care)	Bi-phase PSK, code spread
Receiver Noise Power	= - 174 + 8 = - 166 dbm/Hz	(Don't care)

Chip rate is defined as bit rate times spread factor. The resulting signal will have a $\frac{(\sin X)^2}{X^2}$ power distribution with the first nulls occurring at $\pm$ chip rate.* The peak spectral density of this distribution is 3 db higher than would occur if the distribution were flat; i.e.,



*Bi-phase switched phase modulation is assumed. Other types of modulation may have a different spectral distribution.

Therefore, the peak spectral density of the radiated signal is:

$$Pd = Po + 3 - 10 \log 2R_c$$
$$Pd = Po + 3 - 10 \log 2R_b - 10 \log S$$

where: Pd ≡ Peak spectral density
Po ≡ Chip rate in chips/sec
Rb ≡ Bit rate in bits/sec
S ≡ Spread factor

Therefore, for 100 kb/s system with spread of 100 and power output of 10 watts (+40 dbm), peak spectral density =

$$Pd_{(100)} = 40 + 3 - 10 \log 20 \times 10^5 - 10 \log 100$$
$$= 40 + 3 - 53 - 20 + - 30 \text{ dbm/Hz}$$

For spread of 1000 this becomes: - 40 dbm/Hz
and for no spread at all, the radiated spectral density is - 10 dbm/Hz.
Allowed interference level is chosen at 5 db above KTB + NF or
- 166 + 5 = - 161 dbm/Hz. Therefore, the space isolation required becomes:

Space isolation = - 10 - (-161) = 151 db (no spread)
= - 30 - (-161) = 131 db (spread = 100)
= - 40 - (-161) = 121 db (spread = 1000)

These figures equate to "isolation distances" illustrated in examples below:

Examples

FREQUENCY = 400 MHz
PROPAGATION CONDITION = free space
Then:

a. No spread
151 = 36.6 + 20 log 400 + 20 log d
20 log d = 151 - 36.6 - 52 = 62.4
d = $\log^{-1}$ 3.12 = 2,050 miles

b. Spread = 100

$131 = 36.6 + 52 + 20 \log d$

$d = \log^{-1} 2.12 = 205$ miles

c. Spread = 1000

$121 = 36.6 + 52 + 20 \log d$

$d = \log^{-1} 1.62 = 42$ miles

None of these examples are particularly meaningful since the distance calculated is in all cases beyond line of sight. However, the unfortunate fact of life is that if we are designing for worse case interference at moderate ranges, we must assume line of sight for the interferer which may be on top of a building and an obstructed path for the desired signal. However, even if one is allowed to assume an obstruction loss of 20 db between the packet radio system and the mobile receiver the isolation ranges only reduce to 205, 20.5 and 4.2 miles for the conditions of no spread, spread by 100 and spread by 1000 respectively.

5.0 CONCLUSIONS

The examples given above illustrate the difficult if not impossible problems of spectrum sharing between spread spectrum and conventional systems if we can exercise no control over the spatial distribution or signal directivity of the two systems. Even if a substantial increase in the allowed interference is acceptable, this still does not result in isolation distances that would be acceptable for packet radio. For example, to reduce the space isolation requirements for the 1000 spread system to 1 mile would require that the allowed interference be at a level about 36 db above the receiver noise level for an 8 db noise figure receiver. The 10 watt transmit power level assumed for the packet radio is a reasonable if now low value for the systems being planned; hence, the problem cannot be solved by reducing the transmit power since this would reduce the packet system operating range and hence require deployment of many more repeaters.

This note has only addressed the subject of protection of systems other than packet radio that may share the same frequency band and does not discuss the equally difficult detection problem that results when an interfering transmitter is close to the packet radio receiver. The results emphasize that before further investigation of the spread technique is undertaken, it would be well to attempt to better define the environment within which the packet radio system must operate if spectrum sharing is an objective. In such an evaluation, one should keep in mind that the packet concept even without spread is an effective spectrum sharing technique since many terminals may share a common frequency and information transfer is quite efficient compared to an equivalent bandwidth occupied by voice since the information is digital.